

**SOCIAL INTERACTIVE QUALITY OF PARENT-CHILD  
SCAFFOLDING AS A PREDICTOR OF CHILDREN'S  
EXECUTIVE FUNCTION**

by

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## **ABSTRACT**

The present study examined how specific social interactive patterns of parent-child scaffolding are predictive of the attentional-switching executive functioning (EF) of children, 20 – 29 months of age ( $M = 25.0$ ,  $SD = 2.6$ ,  $N = 37$ ). Prior research has established that directive and elaborative parental utterances are predictive of children's cognitive performance. A ring puzzle was used to assess parent-child scaffolding. Children were assessed on a battery of EF tasks. Contingency scores produced by sequential analysis of parent-child interactive patterns, wherein directive and elaborative parental utterances contingently followed children's puzzle-solving activities, were predicted to be positively associated with children's EF performance. After controlling for children's age, gender, verbal ability, parental education, frequency of both children's problem solving activities and parental utterance type, hierarchical regression revealed that contingent elaborative utterances, but not contingent directive utterances, were predictive of children's EF. Implications of the results for developmental research are discussed.

**Keywords:** scaffolding; executive function; parent-child interaction; sequential analysis

**Subject terms:** child development – social aspects; self-control in children; parent and child; social interaction in children; developmental psychology

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## CHAPTER 1: INTRODUCTION

In developmental psychology, there has been growing interest in the role of social interaction in the development of children's executive function (EF). Executive functions are those cognitive processes (inhibition, attention-switching, working memory) by which individuals plan and organize goal directed activities (Hughes, 2002). Typically, EF is conceptualized within a psychobiological framework, in which the development of EF is a consequence of neurological maturation, specifically of the prefrontal cortex (Bunge & Zelazo, 2006). However, theoretical arguments have been made that in addition to biological maturation, the role of social interaction is ubiquitous in development (Bickhard, 1992; Piaget, 1965/1995; Vygotsky, 1978). Prior theoretical work (Carpendale & Lewis, 2004) has proposed that cooperative forms of parent-child interaction may be more conducive in influencing children's social, emotional, and cognitive development than constraining forms of interaction. Consistent with this view, Neitzel and Stright (2003) found measures of parent-child task scaffolding, as an indicator of social interactive quality, to be predictive of children's later academic performance.

The present study builds upon this work by investigating how specific patterns of social interaction within the context of scaffolding are predictive of children's attention-switching executive function. Specifically, scaffolding is the process by which tutors help plan and organize the activity of children so that

they can *execute* a task that is beyond their current level of ability. Through the incremental learning afforded children by the emotional and cognitively supportive social context of scaffolding, children eventually develop the requisite skills necessary to solve the task independently. Conceptually, the scaffolding process parallels executive function in terms of the cognitive and functional resources it affords children. In both situations an executive, either cognitive functions in the case of EF, or a tutor in the case of scaffolding, helps organize and plan children's goal directed activities; in both situations children have access to a meta-level cognitive resource that assists them in regulating their behaviour. Tutors, therefore, perform many of the functional roles associated with EF on the children's behalf. Consequently, through the social structure of scaffolding parents and caregivers facilitate the development of children's EF by providing a context in which children can gradually master those functions for themselves. For this reason, measures of parent-child scaffolding are expected to be predictive of children's EF.

A number of studies have investigated the relation between scaffolding and children's development of EF. Landry, Miller-Loncar, Smith, and Swank (2002) investigated the impact that parental verbal scaffolding of 3-year-olds had on their later executive functioning at 6-years of age. Scaffolding was defined as maternal utterances that provided children with conceptual connections between referents (e.g., objects, persons, events). Such utterances, Landry et al. suggested, make children responsible for thinking through such conceptual connections during completion of a task. Landry and colleagues predicted that

such scaffolding utterances would be predictive of children's EF. In contrast, utterances that simply tell children how to execute a task do not compel children to work out such connections on their own. Results showed that verbal scaffolding by parents was predictive of children's increased verbal ability at 4-years of age. In turn, this enhanced verbal ability was predictive of greater EF ability at 6-years of age. In a similar study, Smith, Landry, and Swank (2000) found that maternal scaffolding of children at 3-years of age was predictive of greater verbal and non-verbal skills at 6-years of age, even after controlling for SES and frequency of maternal stimulation (total scaffolding and non-scaffolding utterances).

To account for these findings, Landry et al. suggested that through scaffolding, parents provide their children with advanced language models by which to represent problems and their potential solutions. Parents who employed such elaborative, conceptually rich, utterances were also observed to verbally guide their children's activities. This was in contrast to parents who relied instead upon more directive and less conceptually informative utterances. Such parents were observed to directly tell their children what to do, for example, "Get it" and "Put it here" (p. 35), or performed activities on behalf of their children.

### **Parental Scaffolding Utterances: Directives and Elaboratives**

Broadly viewed, the results of the study by Landry and colleagues suggest that instructive parental utterances can be classified into two broad categories: directive and elaborative. The results suggest that, of the two, elaborative utterances are predictive of greater EF development in children. Smith, Landry,

and Swank (2000) have made comparable comments regarding the classification of instructive parental utterances. To illustrate the distinction, they give a hypothetical example of parent-child dyads solving a puzzle. Elaborative scaffolding utterances would highlight the shapes of puzzle pieces and the empty spaces in the puzzle. Such utterances would facilitate the child in making conceptual connections between aspects of the task (e.g., the corresponding relationship between shapes of pieces and shapes of empty spaces in the puzzle). Elaborative utterances, therefore, help children to learn (Smith, et al., 2000). In contrast, less elaborative utterances (i.e., directive) would “involve handing the child the correct puzzle piece or telling the child to ‘do the puzzle’ [which] may help accomplish the task but do not encourage effective problem-solving strategies” (p. 28).

Kruger and Tomasello (1986) also made use of a comparable distinction in utterance types in their study of transactive discussions, both between children and children with their mothers, regarding moral dilemmas. Transactive utterances are those that challenge (i.e., operate) upon another person’s reasoning, or which help another person to clarify his or her thought. Kruger and Tomasello defined transactive questions as “requests for clarification, justification, or elaboration of the partner’s ideas. (Example: “Why do you think the class should use your solution)” (p. 683). Transactive statements were defined as “critiques, refinements, extensions, or significant paraphrases of idea” (p. 683). Analysis of transcripts revealed that children who were paired with their mothers were presented with more transactive questions than children who were

paired with their peers. Kruger and Tomasello interpreted this finding to suggest that parents made use of transactive questions as part of an overall inductive interaction style intended to encourage their children's participation in the discussion and to get them to reason through the problems presented. Consistent with this interpretation, Landry et al. (2000) have suggested that by making requests of their children, parents help their children focus their attention and maintain their interest in problem-solving activities.

Notwithstanding such findings, these studies did not explicitly measure directive utterances as a category of parental utterances. Hess and McDevitt (1984) explicitly coded for such an utterance type. In a longitudinal study, Hess and McDevitt examined the relation between maternal disciplinary and teaching techniques and children's developmental outcomes at 4, 5, 6, and 12-years of age. One of the measures of the study, a block-sorting task, was transcribed for maternal utterances. Maternal utterances were categorized as either "direct commands" or "generative verbalizations" (p. 2020).

Direct commands were defined as "unmoderated imperatives that call for either a verbal or nonverbal response" (p. 2021). Examples of direct commands requiring a verbal response were, "Say it" and "Tell me what this is" (p. 2021). Examples of those requiring a nonverbal response were, "Put it where it goes," "Show me a tall X," "Put it here," and "Look at the top of the block." (p. 2021).

Generative verbalizations were defined as maternal utterances, questions, comments, commands, and requests that called for children to generate a response of their own. "Excluded from this category were invitations to respond

nonverbally, questions answerable with 'yes' or 'no,' and multiple-choice questions (e.g., 'Is this block tall or short?')" (p. 2020).

The results of the study found that even after controlling for maternal verbal ability, SES, and mother's marital status, mothers' use of direct commands with their 4-year-old children during the block-sorting task was negatively correlated with children's verbal ability at 4-years of age, and school readiness at 5 and 6- years of age. Furthermore, the use of direct commands was negatively correlated with mothers' scores on the verbal portion of the Wechsler Adult Intelligence Scale,  $r = -.25$  (p. 2025). Conversely, they found that maternal use of generative verbalizations during the same task was positively correlated with child outcomes.

To refine their findings, Hess and McDevitt tested the possibility that maternal direct command use was a response elicited by children's task related errors and task inattention. That is, mothers may intervene more directly to assist a struggling child. The correlation between direct command use and the number of correct task-specific responses by children was not significant,  $r = .12$ ,  $p > .05$  (p. 2026). Similarly, the correlation between direct command use and child task inattention was also not significant,  $r = .08$ ,  $p > .05$  (p. 2027). Hess and McDevitt interpreted these correlations as suggesting that the direction of effect between maternal direct command use and children's task related difficulties could not be accounted for by child characteristics.

Interpreted more broadly, these correlations can be considered representative of the overall quality of daily parent-child interaction. That is, if

maternal direct command use was not a response to children's task related difficulties, then it is equally likely that maternal direct command use in everyday contexts would also not be a response to children's developmental outcomes. These correlations, therefore, can be taken as suggestive of a direct causal relationship between maternal direct command use and negative child outcomes.

Consistent with the findings of Hess and McDevitt, Landry et al. (2000) have also reported a negative relationship between maternal use of direct commands and children's later outcomes. Landry et al. studied the relation between mothers' use of directive and maintaining behaviours with their children at 2- and 3½-years of age, and those children's later social and cognitive abilities at 4½-years of age. Maintaining behaviours were defined as either verbal or non-verbal behaviours that provided children with choices (e.g., questions, suggestions or comments) directly relevant to their current or immediately prior activities. Directive behaviours were defined as utterances providing children with less opportunity for choice, and instead emphasized expected activities/behaviours. Results found that although maternal directiveness may have a positive influence on development during toddlerhood, by 3½-years of age directiveness was predictive of lower developmental outcomes at 4½-years of age. In contrast, the opposite relation was found for maternal use of maintaining behaviours at both 2- and 3½-years of age. Landry et al. concluded that for scaffolding utterances to assist children across development in a consistent manner, directiveness of parental utterances must correspondingly decrease with children's increasing developmental competencies.



## **Directives and Elaboratives: Implications from Prior Research**

Taken together, the aforementioned studies suggest the following: (a) children's verbal ability is related to their cognitive performance; (b) children's verbal ability, in turn, is related to the verbal richness of parental utterances; (c) parental instructive utterances can be functionally categorized as either elaborative (verbally and conceptually rich) or directive in nature; (d) elaborative utterances are predictive of positive cognitive developmental outcomes in children; (e) conversely, directive utterances are predictive of negative cognitive developmental outcomes in children; (f) the negative impact of directive utterances cannot be completely accounted for by parental verbal ability or SES status; and (g) the use of directive utterances cannot be solely attributable to the characteristics of children.

## **Parental Responsiveness**

The preceding studies have empirically demonstrated an impact of parental scaffolding utterance type on the cognitive development of children. However, what remains to be determined is the relative developmental impact of those utterances, given their contingent occurrence in response to children's ongoing activities. For instance, the previously discussed study by Landry et al. (2000) incorporates such contingent responding in the definition of maternal maintaining behaviours, in that such behaviours are, "related to the activity or object in which children were *currently* [italics added] visually and / or physically engaged *just prior* [italics added] to the mother's request" (p. 362). By either incorporating contingent responding in the definition of parental utterance types,

or failing to measure it independent of the utterance types, the relative developmental contribution of contingent responding, in and of itself, cannot be determined. As such, whether or not the relative developmental impact of differential utterance types varies as a function of when they temporally occur in relation to the children's activities still needs to be addressed. As Landry and colleagues (2001, p. 387) point out: "In spite of the theoretical and clinical significance of the timing of responsive parenting, study designs often do not allow for its direct examination".

Landry et al. (2001) examined the impact of maternal responsiveness on children's cognitive and social development over a developmental course spanning 6 to 48-months of age. Results showed that the frequency of verbal and non-verbal behaviours mothers directed toward their children was positively predictive of positive developmental outcomes. Similarly, Kochanska, Murray, & Harlan (2000) assessed the impact of maternal responsiveness ("promptness, engagement, sensitivity, acceptance, cooperation, availability, following child lead, adjusting stimulation to child state") (p. 225) and level of maternal socialization on the development of children's EF at 22 and 33 months of age. Results indicated that maternal responsiveness measured at 22 months of age accounted for 6% of the variance in children's EF at both 22 and 33 months of age.

Although these studies demonstrate that maternal responsiveness, per se, is predictive of children's cognitive outcomes, they did not specifically measure the cognitive activity of children at the time of the maternal response. Without

such knowledge, the findings of these studies cannot address potential models of how such responsiveness facilitates children's development.

## **Scaffolding**

Originally coined by Wood, Bruner, and Ross (1976), the concept of scaffolding was proposed as a model to account for how certain types of social interaction facilitate children's development. According to Wood et al., the scaffolding process consists of six key sub-processes by which tutors facilitate children's cognitive and emotional development:

- (a) Recruitment: "[Tutors] enlist [children's] interest in and adherence to the requirements of the task" (p. 98).
- (b) Direction Maintenance: Tutors ensure that children's problem solving activities are directed toward achieving particular outcomes that contribute to completion of the task.
- (c) Frustration Control: Tutors manage and regulate children's negative emotional reactions to difficulties in solving the task in order to maintain their commitment to finishing the task.
- (d) Reduction in Degrees of Freedom: "[Tutors simplify] the task by reducing the number of constituent acts required to reach solution" (p. 98).
- (e) Marking Critical Features: Tutors make salient to children features or aspects of the task that are important or relevant for its completion.

- (f) Demonstration: Tutors model “idealized” (p. 98) solutions to task requirements so that they may be imitated by children during completion of the task.

Scaffolding, therefore, is a process that simultaneously aims to regulate both children’s motivation (Recruitment, Frustration Control) and cognition (Reduction in Degrees of Freedom, Marking Critical Features, Demonstration). It is central to the scaffolding process that tutors should accommodate their support to match the current developmental level of the children they are assisting. Tutors must strike a balance between working with children at their current level of competency, and at the same time, challenging them. This requires that tutors not only respond contingently to children’s ongoing activity, but also expand upon that activity and direct it in more challenging directions.

With respect to parental utterances, Direction Maintenance, Reduction in Degrees of Freedom, and Demonstration are comparable to directive utterances. Of the remaining sub-processes, Marking Critical Features is the most comparable to elaborative parental utterances. Notwithstanding such similarities, both the scaffolding sub-processes and the parental utterance types are descriptions of the activities tutors perform while assisting children in solving a task. In the absence of a model of cognitive development, specific explication of how such sub-processes or utterance types facilitate cognitive development remains ill-defined (Bickhard, 1992; Renninger, Ray, Luft, & Newton, 2005). Instructive parental utterance types, and the scaffolding process of Wood and

colleagues, both describe how scaffolding is done, but not why it comes to be done that way.

## **Evolutionary Epistemological Scaffolding**

Bickhard (1992), employing an evolutionary epistemological framework, has proposed that rather than viewing scaffolding as the internalization of social supports and modelled skills (Vygotsky, 1978), that it instead be viewed as the constructivist activity of a child in response to an epistemically uncharted problem space. According to evolutionary epistemology, knowledge must be constructed by agents through their interaction with the world; knowledge cannot be internalized from a source outside the agents' own activity (Bickhard, 1992; Campbell & Bickhard, 1986). Agents are not epistemically free to construct arbitrary knowledge, but must operate within the constraints imposed by the world. These constraints, known as selection pressures, implicitly channel or guide the activity of agents. Stated more formally, selection pressures are implicit background conditions that must be satisfied before an activity can even be defined as a solution to a problem. If the constraints for a given problem are too far beyond an agent's level of ability, the agent will be unable to generate a solution to the problem, as any potential activity tried by the agent will be rendered inadequate by the constraints. In such situations, by reducing or muting the number of constraints (selection pressures) with which an agent must contend, a tutor can reduce the problem space so that the agent is able to construct a partial understanding of the original problem with whatever resources the agent has at its disposal. There are two ways of muting selection pressures:

(a) reducing them by directly blocking them (e.g., reducing task complexity - decreasing the size of the problem space), or (b) providing resources that satisfy them (e.g., external learning aids - increasing the region of the problem space epistemically transverable by the agent). As this process of adaptively attenuating selection pressures continues, the agent slowly constructs, and accumulates, partial understandings of the original problem. Finally, a point will be reached were the agent will be in possession of enough cognitive resources (partial understandings) to solve the original problem. Scaffolding, therefore, is the process by which a tutor reduces or mutes the selection pressures at work in a given problem space so that the tutee is able to construct partial understandings (i.e., cognitive resources) of the original problem, and thereby become able to solve the original problem at a future point in time.

### **Evolutionary Epistemological Interpretation of Directives and Elaboratives**

When viewed from an evolutionary epistemological perspective, it becomes possible to interpret the functional role of elaborative and directive utterances in terms of selection pressures. Directive utterances, by explicitly telling a child what to do, reduce the complexity of the task that the child must contend with; i.e., directives decrease the size of the problem space by directly blocking selection pressures that the child encounters. Elaborative utterances, in contrast, provide the child with external and auxiliary resources that increase the size of the problem space the child can epistemically transverse.

Given such a definition of directive and elaborative utterances in terms of their effect on epistemic selection pressures, their effect upon cognitive and EF development can be considered. Although directives may mute selection pressures to allow for partial constructions, if they are too strong (simplify the task too much) there will be little necessity for the child to develop cognitively, as no new constructions are required to solve the task. This would correspondingly explain their negative effect on cognitive development; they delay the child's development, relative to peers, which appears as a negative outcome at later assessment. For example, Landry and colleagues (2000) found that early in development, directiveness may help development during the toddler years, but that this relation did not hold after toddlerhood. Rather, a shift from directing to maintaining behaviours (i.e., elaborative) by parents had to occur across the developmental course of their children if such behaviours were to continue to support their children's development. Moreover, Landry et al. have suggested that directive utterances may be more cognitively demanding on children than maintaining behaviours. Directive utterances, by distracting children from their current activity, interfere with their attentional focus and require that children first abandon their present activity, and then orient elsewhere. Elaborative utterances, in contrast, are 'about' children's presently occurring activity. Consequently, elaborative utterances do not require that children disengage from their current activity before they can cognitively profit from such parental utterances.

In contrast to directive utterances, elaborative utterances, by augmenting cognitive resources, allow children to engage in novel partial constructions, yet do not permit them to rely solely on previous constructions. With respect to EF, elaborative utterances can be viewed as an auxiliary source of EF available to children; i.e., elaborative utterances fulfil many of the roles attributed to EF: planning (requiring a capacity to disengage from the problem and reflect upon it), attention-switching (disengage from a prior rule or stimulus) and inhibition (disengage from a pre-potent response). By granting children an auxiliary form of EF, children can undertake partial constructions that will eventually result in construction of comparable EF capacities. For this reason, elaborative utterances would be expected to be predictive of cognitive development.

From an evolutionary epistemological framework, the influence of parental responsiveness is explainable in terms of the current cognitive activity of the child. If the child were undergoing a cognitive process of construction, utterances would be predicted to be most beneficial directly at those times when such construction is actively taking place. At the immediate point in time that the child is engaged in problem solving, contingent utterances would serve to either: (a) consolidate the child's partial constructions, in the case of elaborative utterances, or (b) allow the child to form such partial constructions by muting selection pressures, in the case of directives. In contrast, utterances that do not occur during or immediately after the child has undertaken a partial construction may be more difficult for the child to associate with his or her prior activity. That is, the child cannot avail him or herself to these utterances because they no



longer serve as resources that help satisfy the selection pressures that were impinging upon him or her during the constructivist process. By occurring after the fact, non-contingent utterances do not help to reduce, either through the muting of selection pressures or via resource augmentation, the problem space that the child must epistemically transverse.

### **Purpose of Present Study / Ring Puzzle as Scaffolding Context**

The purpose of the present study was to investigate the relation between elaborative and directive parental utterances contingent upon children's immediate cognitive activity, and measures of children's cognitive EF. The present study utilized a ring puzzle task (Figure 1) previously used by Carpendale (1999) to study the effect of social interaction on the development of logical classification. The puzzle, "consisted of four concentric rings that were cut into equally sized pieces, grouped around a middle circle, and surrounded by a solid frame" (p. 136). The frame and all pieces were the same colour. Puzzle pieces differed in their curvature, depending upon which ring they were a member. By virtue of their differing curvatures, incorrectly placed puzzle pieces produced a gap between themselves and neighbouring pieces.

A prior study by Schmid-Schönbein (1990) with this ring puzzle observed that children who spoke to themselves during completion of the task demonstrated increased understanding of the curvature principle in comparison to children who did not. Consistent with this observation, Carpendale (1999) found a similar result when children were asked certain forms of questions as they completed the task. Children who were asked to elaborate upon their

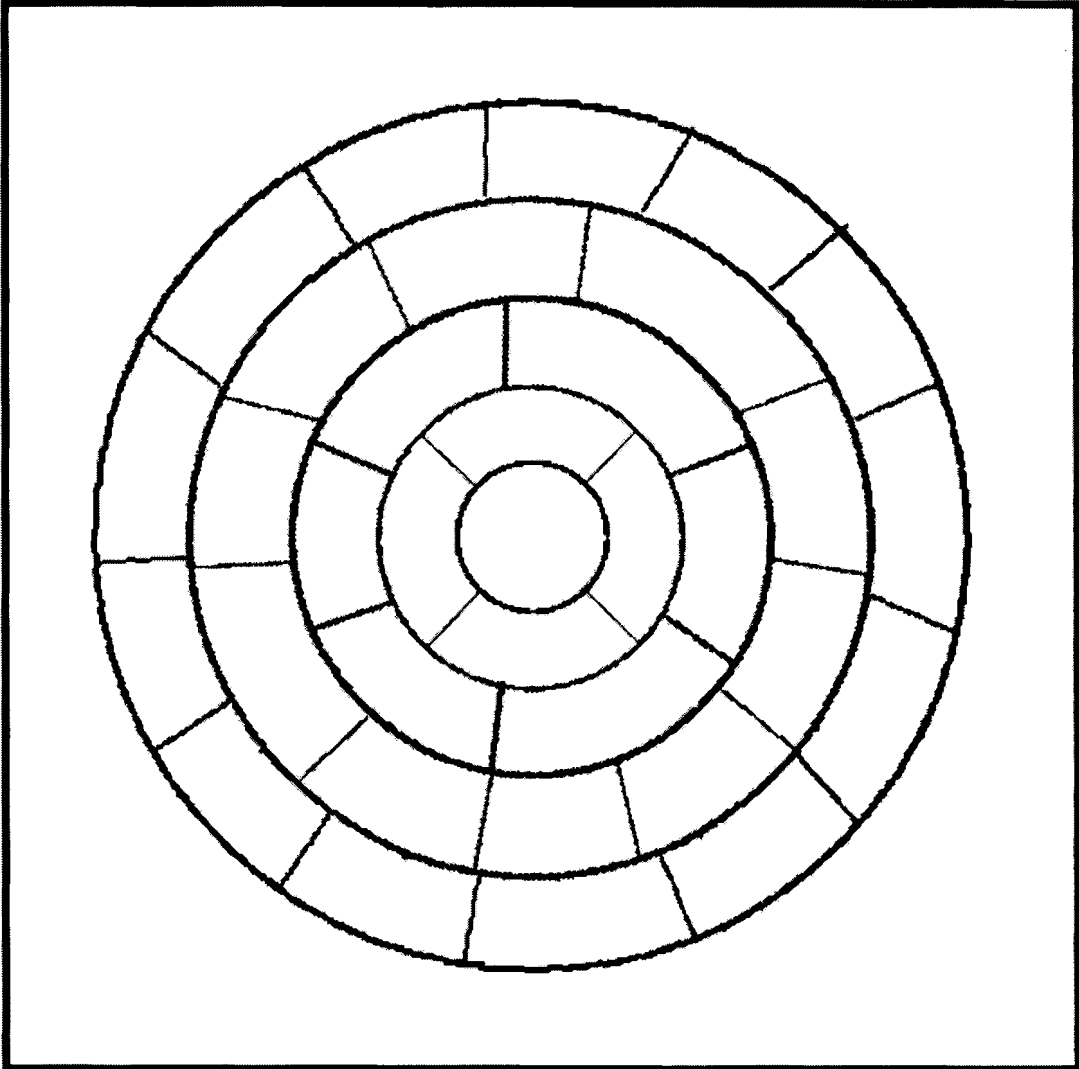


Figure 1. Illustration of Ring Puzzle

activities ("What are you doing now?") demonstrated better performance on the task than children who were asked instead to pass judgment on their activities ("Does that piece fit?") (p. 136). The findings of these two studies are consistent with those of the previously reviewed studies demonstrating a relationship between both children's verbal abilities and tutors' use of elaborative utterances, and children's cognitive performance. Together, the findings of Schmid-Schönbein and Carpendale suggest that the ring puzzle provides a productive context in which to investigate the relationship between tutors' instructional utterances and children's cognitive performance.

## **Hypothesis**

The hypothesis of the present study is that elaborative and directive parental utterances temporally contingent upon the ongoing cognitive puzzle-solving activity of children will be predictive of those children's attention-switching EF. Puzzle solving is a cognitive activity. Although emotional factors may play a role in task completion, they do not pertain to children's cognitive ability to solve the puzzle. If a child is frustrated, he or she may be unable to complete the puzzle on a given day. That does not mean that the child is cognitively unable to solve the puzzle on another day when he or she is not frustrated. Only children's activities that pertained to the cognitive aspects of the puzzle (e.g., manipulation of puzzle pieces) were examined.

Correspondingly, only children's attention-switching EF was examined. The cognitive executive functions, working memory, inhibition, and attention-switching, are generally considered distinct capacities, although this claim has

been contested by some (Barkley, 1997; Kimberg & Farah, 1993). Of these cognitive functions, attention-switching would appear as the one most likely to be manifest during completion of the ring puzzle. If contingent parental utterances derive their effect upon development by being relevant to children's cognitive activity at the time, the measure of cognitive EF assessed needs to be as relevant to the children's puzzle-solving activities as possible.

In the context of children's self-generated puzzle-solving activities, attention-switching EF would manifest itself in children's ability to flexibly adjust their puzzle-solving behaviours in response to the errors they encounter in the course of solving the puzzle. That is, attention-switching EF would be expected to be inversely related to children's tendency to perseverate in unsuccessful puzzle-solving activities. Reciprocally, attention-switching EF would be expected to be directly related to children's ability to successfully complete the puzzle, as by definition to solve the puzzle necessarily entails that children have resolved all their puzzle-solving errors, if any.

With respect to parental scaffolding of the ring puzzle, parental utterances serve to guide children's puzzle-solving activities. If children's puzzle-solving activities are in error, the only way children can viably continue to solve the puzzle is if they change their activity. By commenting upon their children's activities in a temporally contingent manner (i.e., during or after an erroneous activity) parents facilitate their children in either examining their own activity, or switching to a new activity. That is, contingent parental utterances assist children in not perseverating in erroneous activities. Parental utterances can either help

children detect an erroneous puzzle-solving activity, or help them to determine why a successful activity was productive (i.e., why a successful activity was not in error). Parents, therefore, serve as an auxiliary and exogenous form of attention-switching EF for their children. Of the two other executive functions, inhibition and working memory, it is unclear what benefit parents could provide for their children by commenting upon their activity so as to serve the roles of these executive functions. For example, inhibition may stop error perseveration, but would not assist children in switching to a more productive activity. Thus, both with respect to children's own puzzle-solving activities and contingent parental utterances, the executive of function of attention-switching would appear to be the most pertinent to solving the task. Therefore, in the context of scaffolding on the ring puzzle, parental utterances temporally contingent upon children's puzzle-solving activities are most likely to be related to children's attention-switching EF.

As the same constructivist principles of either reducing or buttressing against selection pressures underlie other scaffolding relationships, the quality of the parent-child scaffolding relationship in the context of the ring puzzle task is likely to be representative of previous scaffolding relationships. The developmental influence of these previous scaffolding relationships, in turn, is likely to be reflected in children's attention-switching EF. Therefore, patterns of social interaction involving contingent parental elaboration and direction, observed during completion of the ring puzzle are hypothesized to be predictive of children's attention-switching EF.

## **Overview of Methodological and Data Analytic Approach**

To investigate this hypothesis, children were first assessed on a battery of attention-switching EF tasks. Parents completed a demographic questionnaire and measures pertaining to their children's verbal ability. Parents and their children then completed the ring puzzle. Video footage of the ring puzzle task was time coded for children's puzzle piece manipulation and parental utterance type. Contingency scores of specific patterns of parental responsiveness were created by submitting these two measures to a lag-one sequential analysis (Bakeman & Gottman, 1986): the determination of the statistical probability that a given children's puzzle-solving activity type will be immediately followed in time by a given parental utterance type.

The choice of a lag-one sequential analysis, and the direction of the interaction (parent to child response transitions, rather than child to parent response transitions), was based upon consideration of theoretical models of scaffolding (Bickhard, 1992; Wood et al., 1976). In these models, scaffolding is the process by which adults or more competent peers decompose or simplify a task in order to help a child solve the task. Wood and colleagues have proposed that this decomposition must be sensitive to the child's current abilities. Similarly, Bickhard has proposed that scaffolding works by muting selection pressures that exceed the child's constructivist abilities. Although it is the role of the tutor to decide upon how a task is to be decomposed, the tutor's role only has meaning and efficacy if it is contingent upon the child's current ability. Consequently, it is

the child's activity that drives the scaffolding processes, with the tutor unable to accelerate the process beyond the constructivist capability of the child.

In the context of the ring puzzle, as the task is novel to both parents and children, parents likely will be unable to rely on foreknowledge of their children's difficulties. This will greatly reduce parent's anticipatory scaffolding of their children. Scaffolding of the task must instead be done online during actual completion of the task. As parents will be unable to anticipate beforehand their children's difficulties, parents have to provide scaffolding support contingently, and in response to, the ongoing activity of their children. It is for this reason that a lag-one sequential analysis of the specified direction was chosen.

To test the hypothesis of the present study the following data analytic approach was taken:

1. A hierarchical regression was used to first control for variance in attention-switching EF attributable to (a) children's age, gender, and verbal ability, (b) parental education level, (c) frequency of child puzzle-solving activity types, and (d) frequency of parental utterance types.
2. Contingency scores for the specific patterns of parental responsiveness were entered as sets in the next two steps in the regression, beginning with directive contingency scores, followed by elaborative contingency scores. The change statistics for each step was examined to determine the amount of variance each step

accounted for in attention-switching EF, over and above that attributable to the prior steps in the model.



## CHAPTER 2: METHOD

### Participants

The sample consisted of 100 parent-child dyads recruited by newspaper advertisement from the Greater Vancouver Region and Greater Victoria Region, Canada, as part of the first time-period of an ongoing three-year longitudinal study. The only inclusion criteria for participation in the study were that participants speak English in the home as the primary language, and that children were between 20 and 29 months of age. Parents provided written informed consent on behalf of themselves and their children to participate in the study and to have their session videotaped.

Of the original participants enrolled in the longitudinal study, videotapes of 63 dyads were deemed uncodable due to the participants blocking the view of the camera; these dyads were omitted from analysis.

The final sample consisted of the remaining 37 parent-child dyads. Children (21 male, 16 female) ranged in age from 20 to 29 months of age, with a mean age of 24.97 months ( $SD = 2.61$ ). The accompanying parent was predominately the mother (34 mothers, 3 fathers). Families predominately included two parents; the modal level of education for both parents was a university degree; parental occupation suggested that families were predominately middle class. At the end of each session, parents were paid an honorarium of \$30 dollars.

## **Procedure**

The study was conducted in a furnished laboratory playroom with a one-way mirror through which participants were videotaped. Sessions took approximately one-hour to complete. The same male research assistant presented all tasks to the children. Parents were given instructions to not interact with their children if at all possible while their children completed the tasks.

Children were first presented with the Shape Stroop, Delayed Alternation, and Reverse Categorization tasks (defined below) to assess their attention-switching EF. Children completed the tasks without parental assistance. Afterwards, children and their parents were presented with the ring puzzle task to assess the social interactive quality of parent-child scaffolding.

The puzzle was placed on a table around which the parent and his or her child were seated. Children were instructed: "Look, you and Mommy/Daddy are going to do a puzzle together". Parents were instructed: "Can you help your child solve the puzzle; however you would do so at home?" Two trials of the puzzle were administered. In the first trial, only the central circle and first inner ring were removed. The experimenter did not leave the room during the first trial. In the second trial, the central circle, first inner ring, and second inner ring were removed. During the second trial, the experimenter left the room and did not return until the puzzle was completed. Each trial was videotaped.

Participants were then thanked for their participation and given an honorarium for their participation.

## **Materials and Apparatus**

### **Ring Puzzle**

The puzzle “consist[ed] of four concentric rings that were cut into equally sized pieces, grouped around a middle circle, and surrounded by a solid frame” (Carpendale, 1999, p. 136) (see Figure 1). The frame and all pieces were white. Puzzle pieces differed in their curvature, depending upon which ring they were a member. By virtue of their differing curvatures, incorrectly placed puzzle pieces produce a gap between themselves and neighbouring pieces.

### **Measure of Demographics**

Parents completed a demographic questionnaire regarding: (a) how many adults, older children, same age children, and younger children their child interacts with daily; (b) how many hours per day they and their spouse each spend with their child; (c) how many children regularly live in the home; (d) attending parent’s level of education; (e) spouse’s level of education; (f) attending parent’s occupation, and (g) spouse’s occupation.

For the purposes of this study, only the attending parent’s level of education (Elementary School, High School, Some University, University Degree) was used from the demographic questionnaire in the analysis.

### **Measures of Verbal Ability**

Parents completed two questionnaires regarding their children’s verbal ability. Of the 37 dyads, data was missing on the two questionnaires for five of the dyads. In the case of missing data, children were assigned a score using

item-mean substitution, with the mean being derived from all observable responses of the original 100 participants for the given questionnaire. In the case of missing ordinal-scaled scores (e.g., MacArthur Short Form Vocabulary Checklist – Word Combination Rating; see below), item-mean substitution made use of the mode, rather than the mean, as the preferred measure of central tendency.

### **The MacArthur Short Form Vocabulary Checklist – Level II (Form B)**

The MacArthur Short Form Vocabulary Checklist – Level II (Form B) (Fenson, Pethick, Renda, Cox, Dale, & Reznick, 2000) consists of a checklist of 100 words, age-appropriate for toddlers, from which parents were asked to select those that their child has been observed to use. The MacArthur Short Form also asked parents to indicate how frequently their children make use of word combinations (e.g., Not Yet, Sometimes, Often). Following Carlson et al. (2004), total scores were used in analysis; word combination scores were also included.

### **Internal States Language Questionnaire (ISLQ)**

The ISLQ (Bretherton & Beeghly, 1982) consists of a checklist of 76 words, age-appropriate for toddlers, which refer to internal mental states (e.g., think, look, know). Parents were asked to select those that their child has been observed to use. The ISLQ has been shown to be correlated with general language comprehension and production at 28 months of age (Bretherton & Begley, 1982). Following Carlson et al. (2004), total scores were used in analysis.

## **Measures of Executive Function**

### **Shape Stroop**

The shape stroop task (Carlson et al., 2004; Kochanska, Murray, & Harlan, 2000) measures children's ability to switch attention to a "subdominate perceptual feature" (Carlson et al., 2004, p. 1108). Children were first shown six picture cards: (a) large apple, (b) small apple, (c) large orange, (d) small orange, (e) large banana, and (f) small banana. Children were then asked to point to each of the six cards in turn (e.g., "Can you point to the large apple?"). Next, children were shown three new picture cards. Each card displayed one of the large fruit pictures previously shown, with a picture of one of the small fruit pictures superimposed and centered within the larger picture. Children were then asked to point to each of the small fruits displayed on these cards in turn (e.g., "Can you point to the little apple?").

Following Carlson et al. (2004), test trials were scored according to the following criteria: (a) 0 - child points to the large fruit; (b) 1 – child points to the large fruit but self-corrects; and (c) 2 – child points to the small fruit. A composite score was created by summing the scores on all three test trials, for a maximum possible score of 6 points.

### **Delayed Alternation**

The delayed alternation task (spatial reversal task) measures children's ability to alternate flexibly between search strategies to locate a hidden object among two possible spatial search locations, depending upon the error feedback they receive during previous trials (Landry, Miller-Loncar, Smith, & Swank, 2002).

A sticker was hidden out of children's sight in one of two wells on a testing board, with the wells covered by plastic cups. Children were then shown the board and asked to find the sticker; children were only permitted to select one well per trial. After correct retrieval on three successive practice trials, in which the sticker remained in the same well for each trial, the experimenter hid the reward in the alternate well. When children incorrectly searched at the same side for successive trials, the experimenter hid the object at the same location, until children succeeded. On trials in which children successfully located the sticker, the sticker was hidden in the alternate well on the next trial. Twenty trials were administered in total.

Two variables were extracted from this task. A performance score was created by proportioning the number of successful retrieval trials over the number of completed test trials. A perseveration score was created by counting the number of times children repeatedly searched in a location shown to be wrong on the previous trial. That is, perseveration on a previous error, not searching again at a previously correct location. If perseveration were defined as the number of occurrences in which children search at any previously searched location, the count would equal the total number of trials completed less the number of correct trials; such a count would correlate perfectly with the number of successful trials and contribute no unique variance to the analysis.

### **Reverse Categorization**

The reverse categorization task (Carlson, Mendell, & Williams, 2004) measures children's rule-switching ability. Children were shown twelve red and

blue blocks and asked to sort them by colour into matching coloured buckets. The experimenter first performed six demonstration trials (three of each colour) and then asked children to sort the remaining six blocks. The experimenter then emptied the buckets and introduced the test trials. Children were told that they were going to play a silly game. In the silly game, children were asked to sort the blocks into the bucket of the opposing colour. The experimenter repeated the rule and identified the colour of the block before each trial. There was no feedback throughout the twelve test trials. Self-corrections (children recovering a block they had incorrectly sorted and transferring it to the appropriate bucket) were scored as correct. A proportion composite score was created by dividing the number of correct test trials by the total number of trials completed.

### **Coding Social Interaction**

To create contingency scores for social interaction, video footage of the ring puzzle task was time-coded for parental utterances and child puzzle-solving activities and submitted to a sequential analysis to compute lag-one patterns of interaction (Bakeman & Gottman, 1986).

Videos were first transcribed for both parent and child utterances, and then visually transcribed for child physical observable puzzle-solving activities. The portion of the scaffolding sessions coded consisted of the second trial, in which dyads began solving the puzzle with the central circle, first inner ring, and second inner ring removed, and ending when they were completed.

There are two reasons that the second trial was selected for analysis. In the first trial, dyads were presented with the puzzle with only the central circle and first inner ring removed. This provided dyads with an opportunity to become acquainted with the dynamics of the puzzle and to practice solving it. With only one ring removed all the removed pieces were necessarily of the same curvature. Consequently, children demonstrated few difficulties in solving the puzzle. As a result, there was little need for parents to scaffold their children to help them solve the task. In contrast, removal of the first and second inner rings during the second trial increased the difficulty of the puzzle, as the curvature of the puzzle pieces must necessarily differ. Children, therefore, had a greater difficulty solving this portion of the task. In response, parents correspondingly increased their scaffolding behaviours. Therefore, by coding the second trial it became possible to sample a greater frequency of scaffolding behaviours on the part of both parents and their children.

Transcription was performed using the ELAN multimedia annotator program (<http://www.mpi.nl/tools/elan.html>), which allowed both the auditory and visual elements of the interaction to be transcribed in synchrony. Parent utterances and child physical observable puzzle-solving activities, were time-coded (henceforth, parental utterances and child puzzle-solving activities collectively will be referred to as events). Child utterances were time-stamped and transcribed, but their contents were not assigned behavioural codes. The time period of each event began with the onset of the behaviour and ended with its offset. To ensure precise timing of events, the onset and offset of events were



measured in video frames (1/30 second). Video frames represent the most accurate time interval of measure technically possible, as changes within a video scene are not observable until the next video frame. Precise timing was necessary as the purpose of time-coding events was to allow for their sequential indexing over the course of interaction (i.e., time-codes index the before and after of sequential events). Events were sequenced according to their onsets.

Children's puzzle-solving activities were assigned to the following behavioural codes: (a) Curvature – incorrectly placing a puzzle piece into a given space on the puzzle board; (b) Backwards – incorrectly placing a puzzle piece the wrong way around into the puzzle; and (c) Correct – correctly placing a puzzle piece into the puzzle board. For complete definitions and examples of these codes, see Appendix A – Children Behavioural Codes.

Task-relevant parental utterances were assigned to the following behavioural codes; non-relevant utterances were not coded (cf. Freund, 1990): (a) Directive – utterances by the parent that command, direct, or state the *future* course of action the child should take next; and (b) Elaborative – utterances by the parent that either elaborate upon or evaluate the child's *presently* occurring course of action. Both current context and preceding child utterances were used to disambiguate the assignment of behavioural codes to parental utterances. For complete definitions and examples of these codes, see Appendix B – Parental Behavioural Codes.

The time-codes used in this study were mutually exclusive and exhaustive (Bakeman & Gottman, 1986); for this reason, a Neutral code was assigned to the

time intervals between behavioural events designated by the other codes after all other codes were assigned to the interaction.

The following lag-one transitions (contingencies) were of interest in determining the relation between parental utterance type (Elaborative and Directive) and children's cognitive puzzle-solving activities (Curvature, Backwards, and Correct). Specifically, patterns of interaction were examined in which parental utterances immediately followed children's puzzle-solving activities. The inverse, child puzzle-solving activities following parental utterances, was not examined. By crossing the two types of parental utterances with children's cognitive puzzle-solving activity codes, two sets of contingency scores of interest were generated, with three contingency scores per set.

Directive contingency scores, included:

Curvature → Directives.

Backwards → Directives.

Correct → Directives.

Elaborative contingency scores, included:

Curvature → Elaborative.

Backwards → Elaborative.

Correct → Elaborative.

Computation of contingency scores was based upon the conditional (i.e., transitional) probabilities of observed events displayed by each dyad, rather than duration of events over time. Contingency scores based upon conditional

probabilities represents the most widely recognized and utilized approach to sequential analysis (Martin, Maccoby, Baran, & Jacklin, 1981). The choice to use conditional probabilities of events stems from the fact that dyads varied widely in the length of time it took them to complete the ring puzzle. Use of conditional probabilities controlled for this difference to produce a standardized score of contingency.

As parents often made multiple utterances for the same child activity, child activities were treated as continuing to persist through time after the first contingent response by the parent. Typically, in sequential analysis, an antecedent behaviour is contingently followed by only one consequential behaviour. For example, if a child engaged in the same puzzle-solving activity for five seconds, and the parent produced two utterances during that time, only the first utterance would be considered to contingently follow the onset of that activity. The second utterance would not be considered contingent to the antecedent behaviour. Before another parental response could be considered contingent, the child would need to initiate a new activity. In the present study, by treating children's activities as persisting through time, both parental utterances were regarded as contingent. That is, parental utterances were referenced to the immediately occurring activity of the child, regardless of how long the child had been engaging in that activity. Computation of contingency scores using this approach more accurately reflected the theoretical conception of scaffolding interaction than the traditional approach of a one-to-one correspondence between antecedent and consequential behaviours.

Contingency scores were computed using the limit of phi ( $\Phi$ ), also known as an uncentered correlation:

$$\lim_{d \rightarrow \infty} \phi_d = \sqrt{\left(\frac{a}{a+b}\right) \times \left(\frac{a}{a+c}\right)} \quad (1)$$

As a measure of association, the limit of phi represents the value phi takes on when the total number of Child  $\rightarrow$  Parent transitions comprising an interactive sequence approaches infinity (i.e., with respect to a 2 X 2 contingency table, this limit comes to be numerically represented in cell D) (R. F. Koopman, personal communication, May, 2007). This statistic was chosen in light of the one-to-many approach to determining contingencies. Standard statistical approaches to contingency (e.g., Yule's-Q, phi, Z-scores) require that the total number of transitions comprising an interactive sequence be known. Given the one-to-many approach used in the present study, the total number of Child  $\rightarrow$  Parent transitions is indeterminate; any value calculated will necessarily produce biased estimates of the frequencies of child activities or parental utterances.

Notwithstanding, the function that total number of transitions serves in standard statistical approaches (i.e., as reflected in the value of cell D) is to adjust the relative value of agreements and disagreements in direct relation to the total number of transitions to which they contribute. Consequently, measures of association produced by standard statistical approaches change in value relative to the total number of transitions observed. This occurs regardless if

cells A, B, and C remain constant in the contingency table. That is, two dyads may have the same base rates for both the child's activity and the parent's utterance, along with equal number of contingent events of interest (Cell A), but each will end up with different values of association if they differ in the total number of transitions that occurred during their respective sessions. Given that dyads differed in the number of total Child → Parent transitions it took them to complete the puzzle, the use of standard approaches to contingency, even if feasible, would produce biased measures of contingency amongst the dyads. For an in-depth numerical explanation, see Appendix C. Conceptually, this is problematic because the developmental impact of contingent parental responsiveness is assumed to be in relation to the frequency of its occurrence (cell A), not how that frequency stands in relation to the frequency of contingencies of non-interest (cell D = total number of Child → Parent transitions less cells A, B, and C).

Use of the limit of phi circumvents this problem, as the total number of Child → Parent transitions comprising a session is not relevant. The limit of phi, therefore, produces an unbiased measure of contingency. In essence, the limit of phi isolates, or extracts, the number of contingent events of interest from the total number of transitions in an interaction, such that those contingent events are evaluated independent of the occurrence of other contingencies in the interaction. Conceptually this is desirable, as there is no reason to assume that the developmental importance of one type of contingency varies as a function of the occurrence of other types of contingency.

The limit of phi can also be understood as the geometric mean of the conditional (transitional) probabilities of each of the two events involved in the contingency (i.e., the probability that any given observed Event 1 participates in the contingency, multiplied by, the probability that any given observed Event 2 participates in the contingency). The geometric mean is the preferred measure of central tendency when the data involved are ratio measures (e.g., probabilities). In contrast, the arithmetic mean, which is preferred for quantity and frequency data, produces inflated and biased measures of central tendency when computed for ratio data. Thus, the geometric mean of the conditional probabilities results in a more conservative measure of association between contingent events than the arithmetic mean of those conditional probabilities.

## **Inter-rater Reliability**

### **Attention-Switching EF Tasks**

Inter-rater reliability was calculated for a random selection of over 75% ( $n = 28$ ) of the dyads. Disagreement between coders was resolved through discussion. Intraclass correlations (ICC) were determined utilizing a two-way random, absolute agreement, single measure design for Shape Stroop ( $\rho = .876$ ), Delayed Alternation ( $\rho = .997$ ), and Reverse Categorization ( $\rho = .960$ ).

### **Social Interaction Scores**

The primary investigator coded all scaffolding sessions. To assess inter-rater reliability, a random sample of over 50% ( $n = 19$ ) of the dyads was coded by

an independent rater. Disagreement between coders was resolved through discussion.

Inter-rater reliability was determined for the contingencies of interest, as the contingency scores were the main variables of interest in the analysis. Children puzzle-solving activities, owing to their more objective and physical definition than parental utterances (see Appendix A – Child Behavioural Codes), were not coded for inter-rater reliability. Instead, the focus of inter-rater reliability was on the coding of parental utterances. However, to compensate for sole attention to parental utterances, inter-rater reliability was determined for the contingencies of interest themselves, rather than merely for simple agreement on individual parental utterances. In keeping with the recommendation of Bakeman, McArthur, Quera, and Robinson (1997), this is considered a stricter and more conservative calculation for inter-rater reliability than the more common practice of simple code agreement.

For example, two coders may attain high simple agreement on a given parental utterance type. However, if the parental utterances agreed upon follow a Neutral code, such high agreement does not necessarily reflect agreement on parental utterances that follow a given child puzzle-solving activity (forming the contingencies that will be analyzed). High simple agreements, therefore, may not automatically reflect high agreement on the contingencies (pairing of two behavioural codes) themselves.

As the Kappa statistic can be regarded as a form of ICC, an adequate cut-off for reliability for the ICC inter-rater reliability was based upon that for Kappa.

Following the recommendation of Bakeman and colleagues, kappa should exceed .75 when the number of codes is equal or greater than five. Intraclass correlations (ICC) were determined utilizing a two-way random, absolute agreement, single measure design for parental Elaborative ( $\rho = .904$ ), and Directive ( $\rho = .884$ ) utterances, and for each of the six contingencies (Table 1).



Table 1

*Intraclass Correlations for Child Cognitive Puzzle-Solving Codes and Parental Directive and Elaborative Contingency Scores (Two-way Random, Absolute Agreement, Single Measure)*

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Antecedent	Consequent	
	Elaborative	Directives
Curvature	.773	.853
Correct	.879	.941
Backwards	.879	.872

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## CHAPTER 3: RESULTS AND DISCUSSION

### Descriptive Statistics

Table 2 displays the descriptive statistics for the attention-switching EF task scores, children puzzle-solving activities, parental utterances, and contingency scores of the sample ( $N = 37$ ); Table 3 displays their zero-order correlation.

Although the final sample consisted of the 37 dyads from which video footage could be analyzed, correlations between the measures using the full data set ( $N = 100$ ) were also performed as well for descriptive purposes. Consistent with previous findings by Carlson et al. (2004), maternal education was not correlated with verbal ability: MacArthur Short Form,  $r(72) = .13$ ; ISLQ,  $r(71) = .19$ . Similarly consistent, Shape Stroop was correlated with verbal ability: MacArthur Short Form,  $r(82) = .41, p < .01$ ; ISLQ,  $r(81) = .31, p < .01$ . Also consistent, verbal measures were also significantly correlated: MacArthur Short Form and ISLQ,  $r(81) = .85, p < .01$ .

### Data Reduction

An attention-switching EF composite score was created from children's scores on the Shape Stroop, Delayed Alternation and Reverse Categorization measures. Task scores were first standardized with respect to the initial sample collected ( $N = 100$ ). This was done to prevent sampling biases, owing to the

Table 2

*Descriptive Statistics for Attention-Switching EF Task Scores, Children Puzzle-Solving Activities, Parental Utterances, and Contingency Scores*

Measure	Mean	SD	Min	Max	N
Age (months)	24.97	2.61	20	29	37
Verbal					
MacArthur CDI	60.79	19.91	12.00	95.00	37
ISLQ	30.27	15.47	0	63	37
Attention-Switching EF Tasks					
Shape Stroop (max = 6)	2.81	2.31	0	6	37
Delayed Alternation (DA)*	.35	.28	0	.87	37
DA – Perseveration	2.51	2.97	0	13	37
Reverse Categorization*	.21	.27	0	1	37
Children Behavioural Events					
Curvature	7.16	7.650	0	44	37
Correct	11.86	7.903	0	36	37
Backwards	6.54	5.679	0	21	37
Parental Utterances					
Elaborative	5.89	5.306	0	20	37
Directives	11.03	5.644	3	25	37

Contingency Scores (ranges from 0 to 1)

Curvature → Directives	.197	.192	0	.600	37
Backwards → Directives	.107	.139	0	.530	37
Correct → Directives	.174	.148	0	.561	37
Curvature → Elaborative	.250	.206	0	.717	37
Backwards → Elaborative	.139	.186	0	.620	37
Correct → Elaborative	.130	.164	0	.513	37

*Note.* \* proportion scores

Table 3 Correlations Between Measures at 24 Months of Age (N = 37)

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Age	-	0.04	0.14	0.26	0.05	0.14	0.33*	-0.13	-0.17	0.05	0.28	0.19	0.01	-0.09	0.16	0.33*	-0.20	0.14	0.15	-0.14	0.26
2. Sex		-	0.04	-0.05	-0.18	0.07	0.21	-0.32	0.02	0.26	0.18	-0.07	0.13	0.19	0.13	-0.29	0.06	0.00	-0.11	-0.03	0.25
3. MacArthur			-	0.84**	-0.13	0.54*	0.05	-0.23	-0.08	0.24	0.25	0.14	0.16	-0.05	0.15	-0.18	-0.14	-0.03	0.05	-0.18	0.35*
4. ISLQ				-	-0.05	0.39*	0.10	-0.18	-0.05	0.39*	0.33*	0.19	0.24	0.11	0.23	-0.04	-0.28	0.10	-0.01	-0.15	0.35*
5. Maternal Ed.					-	-0.01	-0.17	0.06	0.13	0.14	0.07	0.09	0.34*	-0.17	-0.13	0.19	0.07	0.37*	0.06	0.33*	-0.07
6. Shape Stroop						-	-0.17	0.09	0.02	0.07	0.36*	0.13	0.06	0.00	0.03	-0.14	0.18	-0.15	-0.02	-0.02	0.52**
7. DA							-	-0.24	-0.06	0.38*	0.13	-0.24	0.09	0.04	0.30	0.30	-0.33*	0.32	-0.23	-0.09	0.54**
8. DA - Per.								-	0.20	-0.16	-0.15	-0.02	-0.09	-0.12	-0.20	0.06	0.14	0.22	0.10	-0.01	-0.06
9. Reverse Cat.									-	0.40*	0.06	-0.34*	0.19	0.30	0.09	0.20	-0.08	0.22	-0.15	0.25	0.47
10. Curvature										-	0.28	-0.16	0.54**	0.44**	0.39*	-0.02	-0.14	0.36*	-0.21	-0.04	0.54**
11. Correct											-	0.45**	0.53**	0.37*	-0.05	0.35*	-0.21	0.12	0.07	0.11	0.45**
12. Backwards												-	0.37*	-0.03	-0.48**	0.00	0.10	-0.06	0.58**	0.02	-0.14
13. Elaborative													-	0.23	-0.18	0.13	-0.07	0.49**	0.16	0.45**	0.21
14. Directive														-	0.23	0.20	0.00	-0.19	-0.17	0.05	0.23
15. Curv. → Direct.															-	-0.06	-0.12	-0.06	-0.40*	-0.02	0.28
16. Cor. → Direct.																-	-0.36*	0.23	-0.01	0.02	0.17
17. Back. → Direct.																	-	-0.16	-0.08	0.18	-0.16
18. Curv. → Elab.																		-	0.03	0.19	0.20
19. Back. → Elab.																			-	-0.08	-0.23
20. Cor. → Elab.																				-	0.06
21. EF Composite																					-

Note. \* p < .05. \*\* p < .01

limited size of the final sample ( $N = 37$ ), from appearing in the standardized task scores. Following Carlson et al. (2004), a principle-components analysis was conducted to determine the correlation between each given task and the overall component the tasks collectively assessed. All tasks loaded upon the initial unrotated factor adequately (i.e., greater than 0.3) (Tabachnick & Fidell, 1983, as cited in Carlson et al., 2004), as displayed in Table 4. Owing to the small size of the final sample, standardized task scores were differentially weighted using their loadings upon the overall component in order to maximize between subject variance. Composite scores were created for participants by averaging the weighted standardized task scores for the four variables assessed by the three tasks.

Consistent with previous results by Carlson et al., the composite EF score correlated with measures of verbal ability: MacArthur Short Form,  $r(82) = .31$ ,  $p = .004$ ; ISLQ,  $r(81) = .34$ ,  $p = .002$ .

### **Family-wise Error Rate**

To test the effect of contingent parental utterance type on children's attention-switching EF, a family-wise error rate of  $\alpha = .05$  was utilized. As two sets of variables were of interest, (a) Directive contingency scores, and (b) Elaborative contingency scores, a Bonferroni correction was employed to calculate the per-test error rate,  $\alpha' = .025$ .

Table 4

*Factor Loadings of the Shape Stroop, Delayed Alternation, Delayed Alternation – Perseveration, and Reverse Categorization Task Scores Upon the First Initial Unrotated Solution Extracted*

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Measure	Loading
Shape Stroop	0.52
Delayed Alternation	0.64
Delayed Alternation – Perseveration	0.66
Reverse Categorization	0.54

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## **Covariates**

### **Gender and Age**

Gender was used as a covariate to control for the possibility that parents may differentially interact with their children depending upon their children's gender. Gender specific differences in parent-child interaction could potentially result from (a) physiological differences in temperament, or (b) parental expectations of stereotypical gender-appropriate behaviour. Beside its potential interaction with parenting style, controlling for gender permitted any potential variability in EF ability attributable to gender (e.g., physiological differences, brain maturation, etc.) to be removed from the analysis.

Children's ages served as a covariate to account for variance in EF attributable to age-related effects. These effects have the potential to allow parents to more easily scaffold their child. Such factors may include brain maturation, cognitive development, and increased proficiency in engaging in social interaction due to increased experience.

### **Verbal Ability**

Children's verbal ability served as a covariate in the analysis as prior research has demonstrated that maternal verbal scaffolding (i.e., elaborative utterances) is predictive of children's increased rates of verbal development (Hess & McDevitt, 1984; Landry et al., 2002; Smith, Landry, & Swank, 2000). Landry and colleagues (2002) have shown that maternal scaffolding utterances are predictive of children's later verbal ability. In turn, children's verbal ability is



broadly related to their intellectual ability (Landry et al., 2001). Carlson et al. (2004, p. 1111) found that at 24 months of age, verbal ability, as measured by the MacArthur CDI, was significantly related to EF performance,  $r(78) = .61$ .

This represents a confound in determining the effect of contingent parental utterance types on children's EF ability. Specifically, if elaborative utterances are related to children's verbal ability, which in turn is related to their EF performance, then it is difficult to determine the direction of effect by which these relations occur. Children who are verbally precocious may be easier to scaffold, and therefore, elicit a greater number of elaborative utterances from their parents. Similarly, the relation between parental elaborative utterances and children's verbal ability may result from shared genotypes between parents and children (Scarr-Salapatek, 1975, as cited in Landry et al., 2002).

The focus of the present study, however, is not whether parental utterances are related to children's EF, as has been observed in prior studies, but rather to investigate if the contingent placement of those utterances with respect to children's ongoing activities lends explanatory merit to such an observation. For this reason, the relation between parental utterance type and children's verbal ability needed to be controlled for in the data analysis to isolate the effects of the contingencies.

### **Primary Caregiver Education Level**

For analogous reasons to those given for including children's verbal ability as a covariate in the data analysis, primary caregiver education level also served

as a covariate. Primary caregiver education level represents a proxy measure of parental intelligence, parental verbal ability, and SES. As previously discussed, the effect of correlated variables between parents and their children needs to be controlled for in the analysis to isolate the effects of parental utterance contingency on children's EF ability. By controlling for primary caregiver education level, individual differences among children's EF attributable to differences in parental intelligence / verbal ability (e.g., shared genotypes) was removed from the analysis of the contingency scores.

### **Frequency of Children's Puzzle-Solving Activities**

As a proxy measure of children's intellectual ability, the frequency of their puzzle-solving activities was entered as a covariate in the data analysis. Children who place more pieces correctly in the puzzle are likely to have more advanced intellectual skills than children who place fewer pieces correctly. Similarly, an inverse relationship between children's intellectual ability and the number of pieces placed incorrectly is likely to hold as well. Reasons to control for this measure in the analysis are analogous to those provided for children's verbal ability and primary caregiver education level, and so will not be repeated.

### **Frequency of Parental Utterance Type**

As previously stated, prior research has shown links between parental utterance type and children's cognitive performance (Hess & McDevitt, 1984; Landry et al., 2002; Smith, Landry, & Swank, 2000). Three aspects to parental utterances are (a) their content, (b) the frequency with which they occur, and (c)

when they interactively occur in relation to prior activities. The first aspect was assessed by the categories of parental utterance type – Directive and Elaborative. Frequency of parental utterances may influence children’s development through reinforcement, and by encouraging children to engage in cognitive activity. By using frequency of parental utterance type as a covariate, it became possible to isolate and test the third aspect of parental utterances – their contingent placement.

Notwithstanding, contingency scores control for the base rates of antecedent and consequential behaviours through the use of conditional probabilities. However, in the case of phenomena that are inherently contingent by nature, contingency scores will invariably account for the same variance accounted for by frequency of the behaviours alone. For example, the variance accounted for by a measure of contingency between the dropping of an object and it hitting the ground, will be the same as that accounted for by measures of either the frequency with which the object is dropped or with which it hits the ground. That is, although both measures may be conceptually distinct, they nonetheless will be highly correlated, as an instance of the empirical phenomena is intrinsically related to the timing of its occurrence. For an object to hit the ground, it must necessarily *first* have been dropped. By controlling for parental utterance type, such potentially spurious results were guarded against.

### **Data Analytic Strategy**

Prior to analysis, data were examined to determine if the assumptions of ordinary least squares regression were met. Standardized residuals showed no

outliers (defined as  $\pm 2.0$  SD). Kolmogorov-Smirnov test and Q-Q plot of the residuals suggested normality. Two, independent samples T-tests, (a) standardized residuals, grouped as above or below zero on the standardized predicted values, and (b) standardized predicted values, grouped as above or below zero on the standardized residuals, indicated no significant difference, suggesting homoscedacity of the residuals. Accordingly, the complete sample was used in the analysis.

Data were submitted to a hierarchical linear regression to statistically test each of the two sets of contingencies of interest. Attention-switching EF composite scores were first regressed on the covariates in the following hierarchical steps: (a) age and gender; (b) primary caregiver education level; (c) MacArthur Short Form Vocabulary Checklist; (d) MacArthur Short Form – Word Combination score; (e) ISLQ; (f) frequency of children’s puzzle-solving activities (Curvature, Backwards, and Correct), (g) frequency of Directive utterances, and (h) frequency of Elaborative utterances.

The purpose of this pattern of steps was only to describe how the variance in EF accounted for by the covariates was distributed; the order in which individual covariates are entered into a hierarchical regression are inconsequential to their collective role as covariates for succeeding variables. No hypothesis tests were performed on the covariates. Descriptive loading of the covariates helped to facilitate comparison between the present study and previous studies. Results of the covariate steps are shown in Table 5.

Table 5

*Summary of Hierarchical Regression Analysis for Variables Predicting 24-Month Attention-Switching EF Composite Scores (Final Model)*

Variable	<i>B</i>	<i>SE B</i>	<i>B</i>	$\Delta R^2$
Step 1				.130
Age	.99	.62	.25	
Gender	4.93	3.23	.24	
Step 2				.039
Primary Caregiver Education				
College	-7.09	5.91	-.32	
University Degree	-4.33	5.44	-0.21	
Step 3				.115*
MacArthur Short Form	.18	.08	.35*	
Step 4				.077
MacArthur - Word Combination				
Sometimes	-13.05	7.76	-.56	
Often	-14.56	7.83	-.67	
Step 5				.001
ISLQ	.04	.20	.05	

Step 6				.259**
Curvature	.62	.23	.47**	
Backwards	-.37	.29	-.21	
Correct	.35	.22	.27	
Step 7				.005
Directives	-.17	.31	-.10	
Step 8				.012
Elaborative	-.36	.40	-.19	
Step 9				.011
Curvature → Directives	-5.70	10.17	-.11	
Backwards → Directives	4.17	12.46	.06	
Correct → Directives	5.81	14.36	.09	
Step 10				.176**
Curvature → Elaborative	12.51	8.70	.25	
Backwards → Elaborative	3.35	8.09	.06	
Correct → Elaborative	42.37	10.58	.68**	

Note. \*p < .05. \*\*p < .01

The two sets of contingency scores were entered as the next two steps in the regression beginning with directive contingency scores, followed by elaborative contingency scores. The change statistics for each step was examined to determine the amount of variance that it accounted for in attention-switching EF, over and above that attributable to the prior steps in the model. The individual coefficients of each contingency type in the final model were not tested. In cases where predictors are highly correlated, interpretation of the individual coefficients to assess the variance they account for in the dependent variable is difficult (Shieh, 2006). Contingency scores, by their very nature, are highly correlated with both the antecedent and consequent events that constitute them. As the change statistic only tests the statistical difference between nested models, correlation between predictors is of non-issue.

Directive contingency scores did not significantly account for any variance in attention-switching over and above that accounted for by the previous covariate steps in the model,  $\Delta F(3,20) = 0.205$ ,  $\Delta R^2 = .011$ ,  $p = .892$ .

Elaborative contingency scores were entered as the last step in the regression. Elaborative contingency scores did significantly account for variance in attention-switching over and above that accounted for by the previous steps in the model,  $\Delta F(3,17) = 5.663$ ,  $\Delta R^2 = .176$ ,  $p = .007$ .

## **Comparisons to Previous Studies**

The finding that elaborative contingencies were predictive of EF is largely consistent with previous studies that found elaborative, but not directive,

utterances predictive of children's cognitive development (Hess & McDevitt, 1984; Landry et al., 2002; Smith et al., 2000). Similarly, this finding is consistent with prior studies that found maternal responsiveness to be predictive of positive developmental outcomes (Kochanska, Murray, & Harlan, 2000; Landry et al., 2001).

However, in contrast to previous studies, it was contingent elaborative utterances and not frequency of elaborative utterances alone, that was predictive of children's cognitive ability. From the hierarchical linear regression, frequency of elaborative utterances served as a covariate and was entered as its own step in the regression. If, in keeping with prior studies, elaborative utterances as an independent measure ought to have been predictive of children's cognitive ability, then this step in the regression potentially should have been significant. Two possibilities present themselves to account for this discrepancy between the present study and previous studies.

### **Non-Significance of Elaborative Utterances as an Independent Measure**

First, the present study and prior studies differ markedly in terms of the duration of social interaction analyzed. In the present study, the second trial of the ring puzzle took approximately five to eight minutes for dyads to complete in a laboratory setting. In contrast, prior studies have utilized durations of interaction ranging from 60 minutes (Landry et al., 2000, 2001, 2002; Smith et al., 2000) to 93 minutes (Kochanska, Murray, & Harlan, 2000) in naturalistic settings. It may be that as an individual measure, elaborative utterances do not have an



effect size large enough to be predictive of children's cognitive development unless a sufficient duration of interaction is sampled so that they may adequately reflect the between subject variance in the population.

Similarly, differences between laboratory and naturalistic settings may influence the rate at which parents make elaborative utterances. In naturalistic settings parents have a greater variety of activities to elaborate upon. In the present study, parents could only elaborate within the context of the ring puzzle. If prior studies found relations between parental elaborations and children's cognitive abilities, it may be because both are global and context independent constructs. The ring puzzle in contrast is context specific. It may be that context-specific elaborations by parents are unlikely to correlate well with a general measure of children's cognitive ability.

Second, as Landry and colleagues (2002) have shown, the effect of elaborative scaffolding utterances on children's cognitive abilities is mediated by its direct effect on children's verbal abilities. Similarly, Hess and McDevitt (1984) found positive relations between maternal generative verbalizations and children's language abilities. Given these prior findings, if children's verbal abilities were predictive of their EF, it might explain why elaborative utterances were not found to be predictive, as controlling for verbal ability would already account for the effect of such a mediating pathway.

In fact, support for such an explanation is suggested by examination of the covariate steps in the hierarchical regression. The covariate step containing the MacArthur Short Form language measure was significant,  $\Delta R^2 = .12, p < .05$ .

The previous covariate in the regression, maternal education, was not significant. Nonetheless, maternal education was shown to be correlated with elaborative utterances,  $r(37) = .34, p < .05$ . The next language measure covariate in the regression, the ISLQ, was not significant. However, this is to be expected as the MacArthur and ISLQ language measures are highly correlated,  $r(37) = .84, p < .01$ . Both of these verbal measures, though, were correlated with children's performance on the Shape Stroop Task: (a) MacArthur,  $r(37) = .54, p = .05$ ; and (b) ISLQ,  $r(37) = .39, p < .05$ . Additionally, both of these measures were correlated significantly with children's EF composite scores: (a) MacArthur,  $r(37) = .35, p < .05$ ; and (b) ISLQ,  $r(37) = .35, p < .05$ . The ISLQ was also correlated significantly with children's Curvature,  $r(37) = .39, p < .05$ , and Correct,  $r(37) = .33, p < .05$ , placement of puzzle pieces. Puzzle-solving activities of the children, in turn, were highly correlated with parental elaborative utterances: (a) Curvature,  $r(37) = .54, p < .01$ ; (b) Correct,  $r(37) = .53, p < .01$ ; and (c) Backwards,  $r(37) = .37, p < .05$ . The puzzle-solving activities of the children, as a set, were entered as a covariate in the regression, prior to elaborative utterances being entered as a covariate, and found to be significant. This was to be expected, as two of the three children's puzzle-solving activities were themselves highly correlated with the attention-switching EF composite score: (a) Curvature,  $r(37) = .54, p < .01$ ; and (b) Correct,  $r(37) = .45, p < .01$ .

Given the highly correlated relationships among the preceding covariates in the regression, and their correlation with elaborative utterances, it becomes clear why elaborative utterances were not significant as a covariate in the

regression – all the variance they accounted for in EF had already been accounted for by the preceding covariates.

### **Data Analytic Implications of Non-Significant Elaborative Utterances**

The fact that elaborative utterances were not significant as a covariate is important with respect to the hypothesis of the present study. Elaborative utterances were entered as the last covariate step before the contingency scores of interest were entered into the regression. Given that this step was not significant, it indicates that all the variance in children's EF attributable to either parental or children characteristics had already been accounted for by the covariates.

These covariates can be conceptualized as measures of either inputs or outputs of a developmental process. For example, maternal education may be correlated (i.e., associated) with elaborative utterances, which in turn are correlated (i.e., associated) with the three puzzle-solving activities performed by children. However, correlations represent measures of association; they do not take into account directionality. For instance, children's puzzle-solving activities might represent a developmental outcome. Elaborative utterances might represent inputs to a developmental process. Although elaborative utterances may be correlated with children's puzzle-solving activities, this does not establish directionality of effect (Smith, Landry, & Swank, 2000). It may be that the correlation between the two results from a third variable, such as the general intelligence of the child, which mediates the correlation. Ultimately, correlations

between elaborative utterances and puzzle-solving activities indicate that they are related with respect to children's development, but cannot address how such relations are structured.

By covarying these measures from the regression, variance in EF attributable to both the inputs and outputs of the scaffolding process was removed from the analysis. The variance remaining in children's EF scores, therefore, can be expected to be related to the structural and temporal relations operating among these measures. It is these structural relations that the contingency scores were created to assess.

## **CHAPTER 4: CONCLUSION**

The purpose of the present study was to determine if directive and elaborative utterances by parents, contingent upon children's immediately occurring cognitive puzzle-solving activities, were predictive of those children's attention-switching EF. Results of the present study found that contingent elaborative responses, but not directive responses, were predicative of children's EF when included in the full model.

### **Interpretation of Results**

As predicted, elaborative contingency scores were predictive of children's attention-switching EF. The results demonstrate that the instructional value of elaborative scaffolding utterances does not lie solely in their content; as directive contingency scores were not significant, instructional content clearly plays a role. Instead, part of what makes elaborative utterances instructional is their contingent delivery with respect to children's immediately occurring activities. Although the content of elaborative utterances may account for what these utterances cognitively do for the child (e.g., increase verbal ability to represent problems), content alone cannot explain how these utterances feed into a developmental process to exercise that effect. If the value of elaborative scaffolding utterances were purely in their instructional content, then the elaborative contingency scores would not have been found to be predictive of EF. Moreover, what the contingency scores suggest is that for instructive

utterances to have any effect at all upon children's development, they must first be contingent to the children's activities, and only second, provide appropriate instructional content. Only through timely presentation to children are instructive utterances able to achieve their effect.

The results of the present study demonstrate a structural and temporal relation between instructive utterances and children's cognitive activities: elaborative parental utterances must follow children's activities in time to exercise their effects. This finding is consistent with an evolutionary epistemological account of scaffolding that would predict that the developmental impact of elaborative utterances is relative to children's current cognitive activities. Nonetheless, the results do not speak to how contingent utterances may causally inform those cognitive activities. That is, the results show that contingent elaborative utterances are predictive of EF; the results do not answer why they should be predictive. Although the results are consistent with an evolutionary epistemological account of scaffolding, they are equally consistent with other views of scaffolding. The empirical findings of the present study, therefore, can be provided with alternate explanations than that proposed by evolutionary epistemology; for example, Vygotsky's (1978) theory of internalization, information processing models of environmental feedback, etc.

## **Limitations**

The first limitation of the present study is that the findings are not generalizable to scaffolding situations outside the age group investigated (24 months). The cognition of toddlers is predominately limited to their immediate

surroundings and activities (Piaget, 1937/1954); i.e., toddlers have restricted representational capabilities. Consequently, the cognitive activity of toddlers is directly manifest in their physical activities. Their physical activities, therefore, can serve as an indicator variable or proxy for their cognitive activities. For parental utterances to contribute to toddlers' development, those utterances must co-occur with those toddlers' physical activities. The result of this scenario is that temporal contingencies (the measure of association of one event following another in time) can serve as an indicator or proxy variable for what actually are scaffolding contingencies of meaning (the association of meaningful utterances co-occurring in relation to cognitive activities of understanding). That is, the present study successfully used temporal contingencies as a stand in for what might be called semantic or epistemic contingencies.

With development, children develop in their representational capacity. Children become capable of representing and using language to refer to past and future activities. This means that children's cognitive activities need no longer map directly onto their physical activities as before. For example, a parent might say, "Do you remember five turns ago when we..." If children remember five turns ago and begin discussing it with their parents, scaffolding contingencies may still be tied to the children's current activity, but such activity might be unrelated to the objective physical interaction in which the parent and child are engaging.

Moreover, the capacity to represent time during interaction means that temporal contingencies, such as assessed by sequential analysis, may no longer

prove useful in the study of scaffolding. For example, suppose a parent makes a comment during the eighth turn of a game about the prior fifth turn. If children are able to index that comment to the fifth turn and cognitively profit from it, then that comment was contingent with respect to scaffolding. In contrast, temporally based analyses of contingency would examine whether or not that comment was contingent to the prior seventh turn, not the fifth. Thus, children's ability to represent time begins to disassociate temporal and semantic contingencies.

Future research could address the empirical question of whether or not scaffolding contingencies remain consistent across development. Regardless, the representational ability of older children requires that scaffolding contingencies not be based upon temporal regularities of social interaction, as was the case in the present study.

The second limitation of the present study is that owing to the small sample size it would be desirable to replicate this study. Moreover, the present study made use of differential weighting in the construction of the EF composite score<sup>1</sup>. These weights may be sample dependent and not generalizable to the population. However, as the sample size was small to start with, the lack of generalizability caused by using differential weighting was considered negligible in comparison.

Nonetheless, it is important to note that correlations among the verbal measures and EF tasks were comparable to those reported by Carlson et al.

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<sup>1</sup> The unweighted composite when used in the analysis produces a pattern of results suggesting a statistical trend that is consistent with that of the weighted composite: Directive contingencies,  $\Delta F(3,20) = 0.555$ ,  $\Delta R^2 = .029$ ,  $p = .651$ ; Elaborative contingencies,  $\Delta F(3,17) = 2.596$ ,  $\Delta R^2 = .111$ ,  $p = .086$ .



(2004) for this age group. Similarly, the finding that elaborative contingent utterances are predictive of children's EF is also in keeping with other studies that have reported elaborative utterances to be predictive of children's EF. Taken together, these two points suggest that the results of the present study have a high probability of being representative of the population. Therefore, replication of the present study with a larger sample may prove to be a highly productive endeavour.

The third limitation of the present study is that the inverse direction of contingency, with children's activities contingent upon parental utterances, was not examined (Freund, 1990). Such contingencies, in conjunction with mother-to-child response contingencies, may create recursive patterns of interaction, which themselves may or may not be predictive children's EF. Furthermore, without controlling for child-to-mother response contingencies, the possibility that children may solicit parental support cannot be investigated (Freund, 1990). Such an effect would represent a form of self-scaffolding (Bickhard, 1992) or self-regulation (Freund, 1990), and therefore, would be likely to have a direct relation to children's EF.

Likewise, any other variables excluded from the full model pertaining to parenting style or parental characteristics (Landry et al., 2002), such as SES, might prove important in understanding how such contingencies operate. Although the present study attempted to control for parental intelligence by using primary caregiver education as an indicator variable, the possibility remains that the relation between scaffolding utterances and children's EF may be mediated

by shared genotypes between parents and their children (Scarr-Salapatek, 1975, as cited in Landry et al., 2002). Conversely, child characteristics, such as inquisitiveness, may make it easier for parents to scaffold their children, and so influence how parent-child interaction moderates or mediates children's development of EF (Landry et al., 2000).

## **Future Research Directions**

To mitigate the limitations outlined, future research should assess the general intelligence and verbal ability of parents, in addition to that of their children. Dynamic systems approaches to modelling social interaction would address the problems of recursion and child-to-mother response contingencies discussed. Notwithstanding these limitations, the present study does demonstrate that for children 24-months of age scaffolding achieves its effects through the timely presentation of instructive parental utterances contingent upon children's current cognitive activities. Implications of this finding are that the effects of social interaction on children's development cannot be reduced to the individual contributions of the participants. What is noteworthy in the present study is that the effect size of elaborative contingency scores is quite robust considering the limited quantity of interaction sampled from each dyad. This suggests that microanalytic techniques that explore interaction in depth are capable of explaining the effect of social interaction on cognitive development with greater precision than other research methodologies. Together, microgenetic analytic techniques, such as sequential analysis, combined with longitudinal assessment to determine direction of causation offers a new

approach to the study of the relation between social interaction and EF development (cf. Hendriks-Jansen, 1996).

## APPENDICES

### Appendix A – Children Behavioural Codes

Children's cognitive puzzle-solving activities were assigned one of the following behavioural codes:

(a) Curvature

- a. Child attempts to manipulate a puzzle piece on the board, and is in error, either because,
  - a. the piece is incorrect (causing a curvature problem in relation to adjacent puzzle pieces), or
  - b. the piece is correct but cannot be properly fitted because of gaps created by misaligned pieces already on the board reducing the size of the space in which to insert the piece (i.e., the space in which to insert the piece is too small).
- b. Timed from the moment the child touches the piece on the board (or has finished bringing a new piece to the board, and which has made contact with the board) until either,
  - a. the child transitions to another puzzle-solving activity, or
  - b. the child has released the piece, and his or her hands have become stationary (resting on table, or stationary in air waiting).

(b) Backwards

- a. Child attempts to place a piece on the puzzle board, and is in error because the piece is oriented incorrectly (wrong side around). This behavioural code applies whether or not the piece is appropriate for the space in which it is to be inserted, as a piece can be neither proper nor improper for a given space on the puzzle board if it is oriented backwards to that space.
- b. Timed from the moment the child touches the piece on the board (or has finished bring a new piece to the board, and which has made contact with the board) until either,
  - a. the child transitions to another puzzle-solving activity, or
  - b. the child has released the piece, and his or her hands have become stationary (resting on table, or stationary in air waiting).

(c) Correct

- a. Child manipulates a piece on the puzzle board, and is correct in the orientation and position of the piece, relative to the space on the board in which it is to be placed. This results in the piece being correctly positioned on the board. That is, the child understands how to correctly place the piece into the puzzle board.

- b. Timed from the moment the child touches the piece on the board (or has finished bring a new piece to the board, and which has made contact with the board) until either,
  - a. the child transitions to another puzzle-solving activity, or
  - b. the child has released the piece, and his or her hands have become stationary (resting on table, or stationary in air waiting).

## Appendix B – Parental Behavioural Codes

Parental cognitive-scaffolding utterances were assigned one of the following behavioural codes:

### (a) Directive

a. Closed-ended suggestive utterances by parents that help the child structure his or her future activities (i.e., telling the child what to do). The defining characteristic of Directive utterances is that the parent's utterance is closed to interpretation and does not foster the child's autonomy. Although Directive utterances may take the form of questions, they are rather directions stated in question form (e.g., "Can you put these two in first?"). When presented in the form of a question, Directive utterances will typically take on a Yes/No format. Examples of Directive utterances include,

- i. "Put these here."
- ii. "Why don't we sort them into big and little pieces?"
- iii. "Let's start on the outside ring first."
- iv. "Where do you think this piece goes?" (while simultaneously handing the piece to the child)

1. As the parent is handing the child the piece, the question is posed as a directive/command telling the child to put the piece into the puzzle.

- b. This code is analogous to the scaffolding functions of “Reducing Degrees of Freedom” or “Task Decomposition” proposed by Wood and colleagues (1976).

(b) Elaborative

- a. Utterances made by parents that pass evaluation or draw the child’s attention to the efficacy of the child’s current activity in solving the puzzle.
  - i. “Does it fit in here, or does it fit there do you think?”
  - ii. “Is that the one?”
  - iii. “That one? I’m not sure.”
  - iv. “You know, that one doesn't seem to fit exactly right.”
- b. Utterances made by parents that meta-comment on the child's activity
  - i. “You put that in the middle, OK.”
  - ii. “They turn around, don’t they?”
  - iii. “That’s a tricky one.”
  - iv. “Yeah, it's tricky, isn't it?”
  - v. “Half done.”
  - vi. “Almost done, one piece left.”
  - vii. “Oh, you don't know were that one fits in?”
  - viii. “Hmm...I don't know. I think that one's a smaller piece.  
Does it go there?”
  - ix. “See how there's a piece missing?”



- c. Parental utterances that illustrate the principles of the task
  - i. Verbal demonstration by the parent of a critical principle of the task's design:
    - a. the differing curvature of the puzzle pieces create gaps with respect to adjacent pieces in the puzzle, and
    - b. the ability of pieces to slide within a ring, creating lacunae.
  - ii. "Look, see how they have different curves."
  - iii. "See, they can slide about, like train tracks."
  - iv. "Oh, that one's too big of an arch isn't it? That one doesn't really fit around the circle."
- d. Elaborative utterances are differentiated from Directives by the time frame suggested by the utterance with respect to the ongoing activities of the child. Elaborative utterances take as their target the presently occurring activity of the child; Directive utterances take as their target potential future activities of the child.

## Appendix C – Comparison of Phi and the Limit of Phi

What follows is a numerically based example of the mathematical differences between phi ( $\Phi$ ) and the limit of phi. In turn, it will be shown that these differences tacitly impose theoretical assumptions upon the study of scaffolding that are unwarranted. These assumptions will be discussed.

To start, suppose the existence of two behavioural states for a child (states: B, C), and two states for a parent (states: D, E). Thus, there are four behavioural states that will be sequenced to represent an instance of social interaction. These states are mutually exclusive and exhaustive. Thus, (a) only these four states can comprise the sequence, and (b) the same state cannot follow itself.

Consider the following sequence:

C, D, C, E, C, E, C, E, C, E, C, E, B, E, B, D, B, D, B, D, B, D, B, D, B, E

Arrange this sequence in a 2 X 2 contingency table (Table 6), with the child as the antecedent, and the parent as the consequent.

Next, compute  $\Phi$  using the formula:

$$\phi = \frac{ad - bc}{\sqrt{(a+b) \times (a+c) \times (b+d) \times (c+d)}} \quad (1)$$

Thence,  $\Phi = .547$ , for this contingency table.

Table 6

*Example Contingency Table - One*

---

Child	Parent		Total
	E	E' (D)	
C	5 (Cell A)	1 (Cell B)	6
C' (B)	2 (Cell C)	5 (Cell D)	7
Total	7	6	13

Now, consider again the same sequence:

C, D, C, E, C, E, C, E, C, E, C, E, B, E, B, D, B, D, B, D, B, D, B, D, B, E

Now, drop the last three Child → Parent pairs of (B, D) from the sequence.

Thus,

C, D, C, E, C, E, C, E, C, E, C, E, B, E, B, D, B, D, B, E

Once again, arrange this sequence in a 2 X 2 contingency table (Table 7) and compute  $\phi$ . Thence, for this new sequence,  $\phi = .356$ .

The point to observe from the above exercise is that the values for cells A, B, and C have remained unchanged between the two tables. Only cell D has changed value as a function of the number of Child → Parent transitions comprising the sequence. As a result, the value of  $\phi$  is lower in the second table compared to the first table.

The reason for this reduction in  $\phi$  is that in a contingency table, agreements and disagreements are measured on the diagonals. Cells A and D represent agreements: respectively, contingent events of interest, and contingent events of non-interest. Cells B and C represent disagreements. Now, compare cells B and C of the two tables, relative to the total number of Child → Parent transitions. Although the values of cells B and C have remained unchanged between the tables, the proportions of their sum, relative to the total number of Child → Parent transitions, have changed: 3/13 for the Table 6, 3/10 for the Table 7. Hence, there are more disagreements in Table 7 than Table 6, merely because of a decrease in the total number of Child → Parent transitions.

Table 7

*Example Contingency Table - Two*

---

Child	Parent		Total
	E	E' (D)	
C	5 (Cell A)	1 (Cell B)	6
C' (B)	2 (Cell C)	2 (Cell D)	4
Total	7	3	10

---

Now, repeat the same procedure for cells A and D, which represent agreements:  $10/13 = 0.77$ , for Table 6,  $7/10 = 0.7$  for Table 7. Thus, there are also fewer agreements in the Table 7 than Table 6. Remember, that between the two tables cell A has remained unchanged; only cell D has changed. Therefore, Table 7 manifests both, less agreement, and more disagreement, than Table 6. Moreover, this difference between the tables has resulted merely from a change in the total number of Child → Parent transitions, which in turn, manifests itself in a change in the frequency of contingent events of non-interest (Cell D). For this reason, Table 7 has a lower value of  $\Phi$  than Table 6.

Conversely, another point is revealed by this analysis. Cell D is a function of the total number of Child → Parent transitions: total number of Child → Parent transitions minus cells A, B, and C. Therefore, the greater the number of contingent events of non-interest (cell D), accompanied by a corresponding increase in the total number of Child → Parent transitions, the greater the value of  $\Phi$  becomes.

Within the context of statistically quantifying scaffolding, this is problematic. In the present study, there are two parental utterance types, Elaborative and Directive, and three children's activity types, Curvature, Backwards, and Correct. Suppose that the contingency of interest is "Curvature → Elaborative", and represented in cell A. Cell D, therefore, would represent Child → Parent contingencies of non-interest that involve neither Elaborative nor Curvature behavioural codes. These contingencies would be "Backwards → Directive", and "Correct → Directive". What this analysis has shown is that a

dyad may obtain a higher value for  $\Phi$  than other dyads, paradoxically because that dyad has more Directive utterances contingent upon the Backward and Correct children's activity types.

Theoretically, there is no reason to posit such a relationship between differing contingencies. Instead, such a relationship is an artefact atheoretically imposed by the internal mathematical dynamics of the  $\Phi$  statistic. If anything, it is more reasonable to argue that the relative developmental importance of elaborative contingencies should drop in relation to an increase in parental use of Directive utterances. More reasonable yet is to assume no functional relationship between different types of contingencies. That is, the relative developmental value of a given contingency type does not fluctuate (as reflected in the value of  $\Phi$ ) as a function of the frequency of other contingency types also occurring over the course of interaction.

In the present study, to circumvent this problem the limit of phi was selected as the statistic of contingency. Unlike the  $\Phi$  statistic, the limit of phi is unaffected by the frequency of contingent events of non-interests (Cell D). The limit of phi is as follows:

$$\lim \phi_{d \rightarrow \infty} = \sqrt{\left(\frac{a}{a+b}\right) \times \left(\frac{a}{a+c}\right)} \quad (2)$$

The limit of phi is equivalent to the value  $\Phi$  takes on when the frequency count of cell D approaches infinity (R. F. Koopman, personal communication, May, 2007).

For example, when  $\Phi$  is computed for Tables 6 and 7, using arbitrarily selected values for cell D of increasing magnitude, holding cells A, B, and C constant, the following pattern results (see Table 8).

The limit of phi, therefore, controls for differing frequencies between dyads in the number of contingent events of non-interests, by rendering them an infinite. As previously stated, cell D is a function of the total number of Child  $\rightarrow$  Parent transitions, less cells A, B, and C. Consequently, the limit of phi, by mathematical definition, also simultaneously controls for differences between dyads in the number of Child  $\rightarrow$  Parent transitions it took them to complete the task. This standardizes the measure of contingency between dyads. Only the contingency of interest (cell A), relative to the frequency of the base rates for the two events comprising the contingency (cells A + B, and cells A + C), influences the between-subject variance in the contingency scores.



Table 8

*Increasing Values of Phi ( $\phi$ ) for Contingency Tables 6 and 7, as Cell D Approaches Infinity, Given That Cells A, B, and C Remain Constant*

Value of Cell D	$\phi$
40	0.736247735
50	0.743088047
60	0.747705984
70	0.75103327
80	0.753544651
90	0.755507463
100	0.75708375
200	0.764244255
300	0.766655841
400	0.767866332
500	0.768594137
600	0.769079972
700	0.769427306
800	0.769687977
900	0.769890821
1000	0.770053159
10000	0.771370185
1000000000	0.771516748
$\infty$	0.771517

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